

# **SUPERCritical PF**

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# **DEVELOP SUPERCRITICAL COAL-FIRED UNITS TO OPTIMIZE CHINA'S THERMAL POWER STRUCTURE**

## **ABSTRACT**

Since 1980s, China's electric power generation has been dominated by conventional coal-fired power plants including a large number of small coal-fired units rated at 50MW and below. China is currently taking measures to optimize its electric power structure. It is considered that the most practical and effective technical solutions currently available are to employ supercritical units to improve coal utilization efficiency and reduce pollutant emissions from coal combustion.

## **1 THE DEVELOPMENT STATUS OF ELECTRIC POWER INDUSTRY IN CHINA**

Since the implementation of the open to outside and reform policy in the early 1980s, China's electric power industry has achieved rapid development. The total installed generating capacity reached 100GW in 1987 and exceeded 200GW in 1995. In order to meet the increasing demand for national economic and social development, China's electric power industry has been kept rapid growth and the newly installed generating capacity has been reached over 15GW annually during the past 8 years from 1991 to 1999. By the end of 1999, the national total generating capacity had been amounted to 298.8 GW with a total electric power production of 1233TWh. As of the end of April in 2001, China's total installed generating capacity has surpassed 300GW.

Being the leading economy in coal production and consumer and with the coal as its major primary energy resources in the world, China's electric power generation has been dominated by conventional coal-fired power plants. Since 1990, the installed thermal power generating capacity has remained at approximately 75% of the total installed capacity in China's electric power industry, with hydropower about 24% and nuclear power less than 1%. The electricity production of thermal power plants accounts for over 80% of the total power production, of which 76% are from coal-fired power plants, which is showed in Fig 1 and Fig 2.

Fig 1 China's Installed Generating Capacity from 1987 to 1999

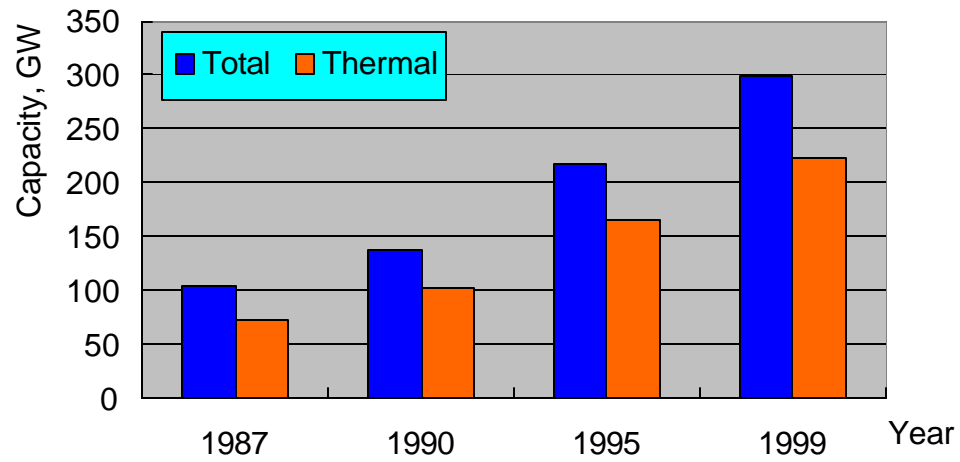
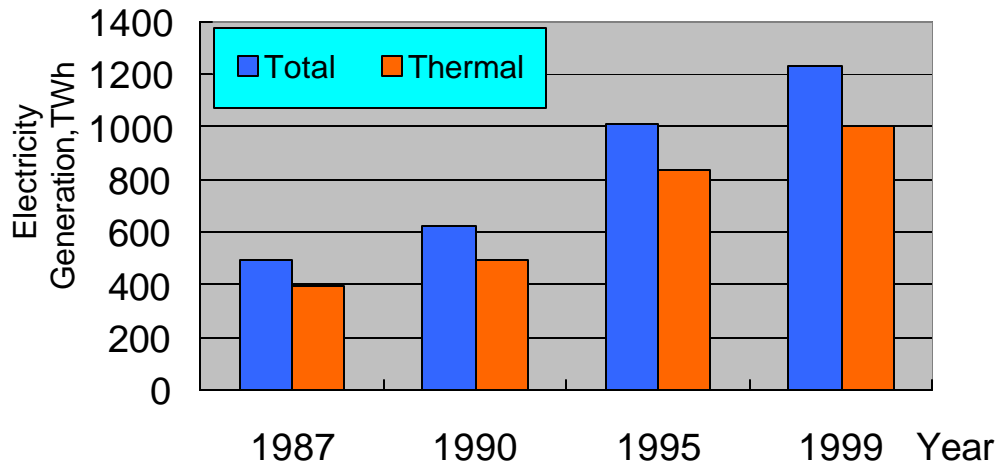


Fig 2 China's Electricity Generation from 1987 to 1999



By the end of 1999, there were total 81 power plants each with installed capacity of 1000MW and above, of which 14 are hydropower plants, 66 thermal power plants and 1 nuclear power plants. In addition, there are 23 power plants are being under construction. Table 1 shows the structure of thermal power plants in China in 1999

Table 1 The structure of thermal power plants in China in 1999

Unit Capacity, MW	Number of Unit	Combined Capacity, MW	Share %	Steam Parameters
Total installed thermal power capacity	Over 3500	223434	100	
500-660	23	13300	5.9	16.6Mpa/538/538°C
320-362.5	50	17252	7.7	16.6Mpa/538/538°C
250-300	170	51136	22.3	16.6Mpa/538/538°C
200-220	195	39140	17.5	12.2Mpa/535/535°C
110-125	152	18915	8.5	8.8Mpa/535°C
100	144	14400	6.4	8.8Mpa/535°C
Less than 100	About 2800	About 70000	About 31	

Currently, the supply and demand in China's electric power markets has been basically balanced in part areas of China, but this balance remained at a low level for power consumption. Although China's total installed generating capacity and total power generation has ranked second in the world, the installed capacity per capita in China is still only 0.237 kW, and the annual average electricity generation per capita is only 979 kWh. Compared with industrial economies, the power generation equipment as well as its technical and economical operating performances of most coal-fired units in China is relatively backward. The national average net coal consumption of thermal power plants is still as high as 399 g/kWh in 1999, which is about 65 g/kWh higher than that of the industrial developed economies.

The above statistic results show that China's electric power generation is dominated by thermal power plants with relative low share of large size units. The combined capacity with units rated at 500MW and above only accounts for less than 6% of the total thermal capacity, of which there are only 16 units rated at 600MW or 660MW. Considering the capacity composition of the total 223GW installed thermal power units, over 97% of them employed the steam parameters with sub-critical pressure and below. Only 5200MW of supercritical units are under operation in China by June of 2000, which accounts for about 2.3% of the total installed thermal capacity. The combined capacity of the units rated at 300MW and above accounts for 36%, units rated at 100-220MW being 33%, and the rest units rated below 100MW being 31%. There are more than 40000MW of small units rated at 50MW and below accounting for about 18% of the total thermal capacity. As the higher net coal consumption and serious pollutions caused by the existing small units have resulted negative effect on the environmental protection and effective utilization of primary energy resources, the State Power Corporation of China has implemented a plan to shutdown and close certain capacity of small coal-fired units step by step. According to the plan, at first a total 7740MW capacity of small units will be shutdown and closed within three years from 1998 to 2001, and then a total 6250MW capacity of small units will be shutdown and closed from 2001 to 2004. By the end of 2004, The State Power Corporation of China will shutdown a total capacity of 14000MW

small coal-fired units. This will leave a large capacity space for the development of the advanced large size thermal units.

## **DEVELOP SUPERCRITICAL UNITS TO OPTIMIZE CHINA'S THERMAL POWER STRUCTURE**

In order to further improve thermal plant efficiency and to reduce pollutant emissions caused by coal utilization, over the past decades clean coal technologies such as CFBC, PFBC-CC, and IGCC have been developed and demonstrated in industrial economies. The IGCC plant efficiency has been reached 43% and can reach 45% after further improvement, meanwhile the pollutant emissions are only about 10% to 20% of the conventional coal-fired units equipped with De-SO<sub>x</sub> and De-NO<sub>x</sub> systems. Although these clean coal technologies are the promising technologies in the 21<sup>st</sup> century, the largest capacity of single units employing these clean coal technologies is still at the level of 200MW and 300MW class, they are still under demonstration from the point of view for the development to large size capacity. Therefore, it is impractical for China to employ these clean coal technologies in the near future to meet the increasing demand for the electric power development.

It is well known that the supercritical units have higher plant efficiency because of the higher steam parameters. Therefore the supercritical units have lower net coal consumption as well as lower pollutant emissions. Generally speaking, The net plant efficiency of the supercritical units employed the steam parameters of 24.1MPa 538/538 is about 2~2.5% higher than that of the sub-critical units with the steam parameters of 17.1MPa 538/538, while the net plant efficiency of the ultra-supercritical units with the steam parameters of 31MPa 566/566/566 is about 4~6% higher than that of the sub-critical units with the steam parameters of 17.1MPa 538/538.

To date, the supercritical and ultra-supercritical units have been developed into proven and mature technologies worldwide. Over hundreds coal-fired supercritical units have been successfully into operation for many years worldwide. Recently, several large size supercritical units employed the steam parameters of 28.0-30.0 MPa/580 /600 have been into commercial operation with the net plant efficiency of 45%. The largest supercritical unit has reached a capacity of 1300MW. Some industrial economies have set the near-term target to develop the 1000MW supercritical units with the steam parameters of 31MPa/600 /600. Furthermore, Some industrial economies and manufacturers have planned to develop the next generation of supercritical units to employ steam parameters of 35-40MPa/700 /700 with the net plant efficiency close to 50-55%.

The current net coal consumption of advanced supercritical units is about 310~320 g/kWh and that of the ultra-supercritical units can be taken as 290 g/kWh. However, the net coal consumption in China in 1999 was still as high as 399g/kWh which is about 80 g/kWh higher than that of the supercritical unit and 110 g/kWh higher than that of the ultra-supercritical units. In addition, the net coal consumption of existing small thermal units in China is as high as 550g/kWh or more. Therefore, more than 15 Mt of coal can be saved annually when the small coal-fired units with a combined capacity of 14000MW are substituted with the advanced supercritical units.

Therefore, In addition to develop some gas-fired and LNG-fired combined cycle units as well as clean coal demonstration units, to further develop large size coal-fired supercritical units with high steam parameters will be the most effective technical solutions for China to optimize its electric power structure. This will greatly improve coal utilization efficiency and reduce pollutant emissions in the near future.

## **THE CHINA'S PREVIOUS WORK AND CURRENT APPLICATION OF SUPERCRITICAL UNITS**

China imported the manufacture technologies of 300MW and 600MW sub-critical units in the early 1980s and successfully realized domestic manufacture of these capacity units within a short period of time through technology renovation and system process optimization. The 300 MW and 600MW sub-critical units manufactured domestically after optimization have reached advanced levels of the same kind units in the world. To date, China has manufactured about 100 sub-critical units each rated at 300MW and 6 units each rated 600MW. These units have become into the main units in China's electric power industry. During this period, the domestic manufacturers have a better understanding to the design, installation, commissioning, management and operation technologies for these large size sub-critical units.

To date, there are over 10 supercritical units have been into operation and more than 10 supercritical units have been approved or planned to be constructed. All supercritical units under operation or construction in China are imported ones. Table 2 shows the current supercritical power plants under operation and construction in China. The first 600MW supercritical pressure units were put into operation in succession in 1990s. Two 600MW units supplied by ABB were commissioned at Shanghai Shidongkou No.2 Power Plant in 1992. Afterwards through equipment improvement and operation optimization, although the heat rate has not reached the design value, the units have been in stable operation with very high availability. The project also trained a team of installation and operation technical personnel, and at the same time the domestic manufacturers also sub-contracted the manufacture of part of main and auxiliary equipment, which has laid a good foundation for developing domestic supercritical units. Supercritical units imported from Russia have a total capacity of 4800MW. Four 300MW units and five 500MW units have been commissioned and into operation, two 800MW units will be commissioned next year. These units are in stable operation after testing and adjustment. The Chinese technical personnel and operators have got a better understanding to the operation technology for these supercritical units.

Table 2. Table 2 shows the current supercritical power plants under operation and construction\* in China.

Name of Plant	Manufacturers	Number of units	Capacity, MW	Steam Parameters, MPa/ /
Sgidonkou No.2	ABB	2	600	24.2/538/566
PAnshan	Russia	2	500	23.54/540/540
Huaneng Nanjing	Russia	2	320	25.0/540/540
Yinkou	Russia	2	300	25.0/545/545
Yimin	Russia	2	500	23.54/545/545
Suizhong	Russia	2	800	25.0/545/545
Zhangzhou Houshi*	Mitsubishi	6	600	25.4/542/569
Waigaoqiao*	Alstrom	2	900	25.0/538/566

## 2 TECHNICAL ROUTINES FOR CHINA TO DEVELOP SUPERCRITICAL UNITS

In order to improve the development of the supercritical units in China's electric power industry, the Chinese government has listed the development of the supercritical units as one of the key project on the research & development of equipment and domestic manufacture during the tenth five-year plan. The State Planning and Development Committee has approved to build two 600MW supercritical units as the demonstration project for domestic development of supercritical units at the Qinbei Power Plant in Henan Province. The State Economic and Trade Committee has provided special sponsorship for the domestic development of supercritical units.

Concerning the supercritical units project at Qinbei Plant, China will take the policy to import equipment as well as the design and manufacture technology, meanwhile to increase the proportion of sub- contracted key equipment manufacture domestically. It is aimed that 70% of the equipment for the first two supercritical units to be manufactured domestically. Considering the proven experience based on the domestic manufacture of 300MW and 600MW sub-critical units as well as the availability of supercritical units can reach 90%, the unstable operation period for the first domestic supercritical unit should be with one year and its availability should be not less than 85%.

With regards to the steam parameters for the supercritical units to be developed in China, considering the development history and current trends for supercritical unit in the world, through statistic on steam parameters of supercritical units supplied by main turbine manufacturers under operation or to be constructed in the world since 1990s, the findings show that the advanced supercritical units each rated at 600MW have employed increasing steam parameters from 24.2MPa/538/566 to 24.2MPa/566-580/566-580 and is currently approaching to 24.2MPa/600/660 The development of alloy-steel and operation records of supercritical units worldwide have also shown that supercritical units employing steam parameters of 24.2MPa/566/566 is a proven and mature technology.

The supercritical units currently under operation in China employ the steam parameters of 24.2MPa,538/566 , which is at the level of 1980s. It has proved that. According to the current development status of electric power industry in China, meanwhile considering the development of ultra-supercritical units in the near future, it is suggested that the supercritical units to be developed in China be based on 600MW unit and employ steam parameters of 24.2MPa,566/566 .

## **CONCLUDING REMARKS**

Currently in China there is an open electric power market, the advanced technologies from industrial economies have entered into this market. The leading power equipment manufacturers and power companies worldwide have a good co-operation with China. In order to meet the increasing demand for China's electric power development as well as to improve coal utilization efficiency and reduce pollutant emissions from coal fired power plants, China will take effective measures to optimize the thermal power structure through combination of technology and equipment import to greatly develop domestic supercritical units.

# Develop Supercritical Coal-fired Units to Optimize China's Thermal Power Structure

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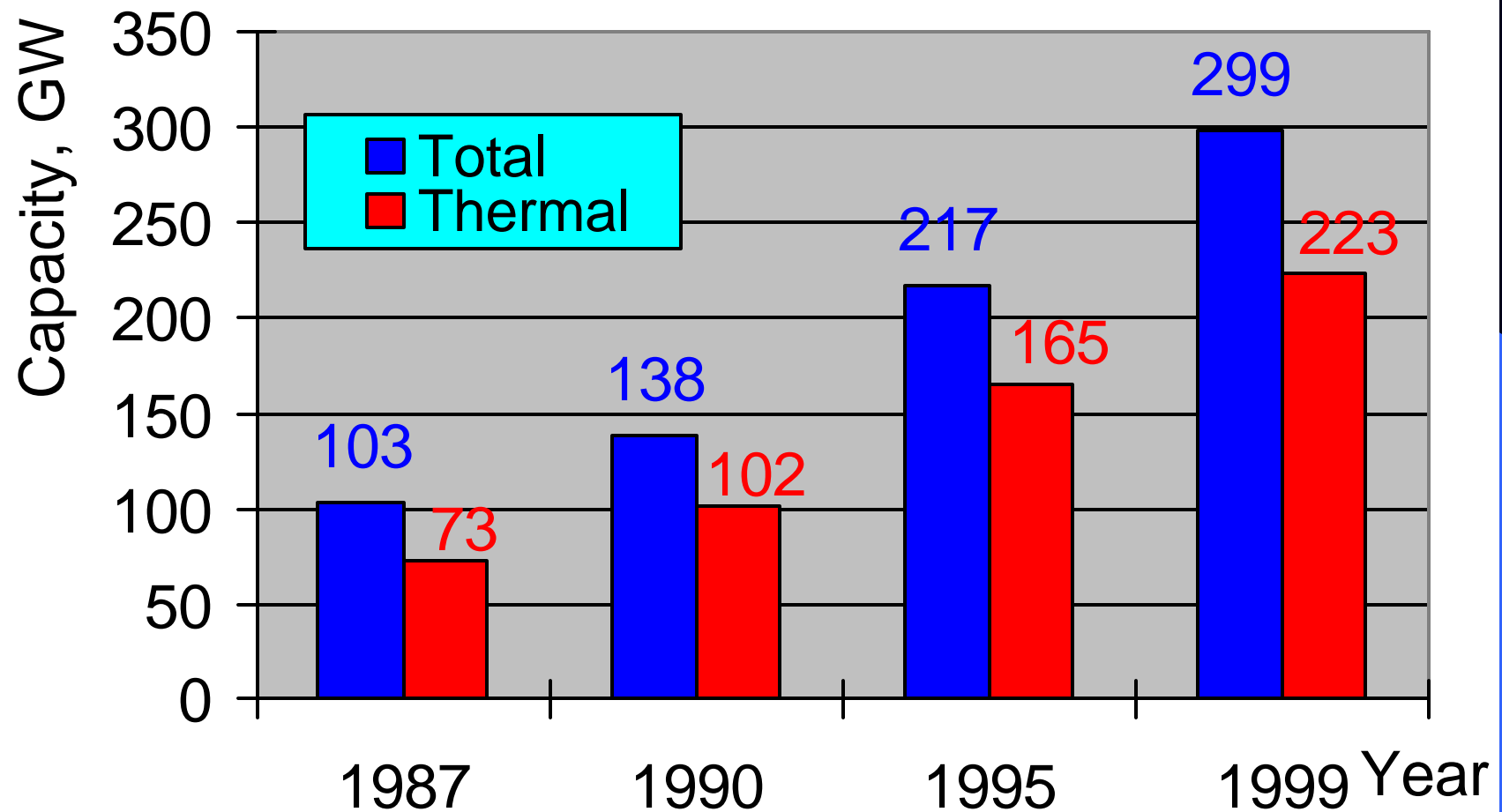
# Develop Supercritical Coal-fired Units to Optimize China's Thermal Power Structure

- Current Status of Electric Power Industry Development in China
- Develop Supercritical Units to Optimize China's Thermal Power Structure
- Current Application of Supercritical coal-fired Units in China
- Technical Routines for China to Develop Supercritical Coal-fired Units

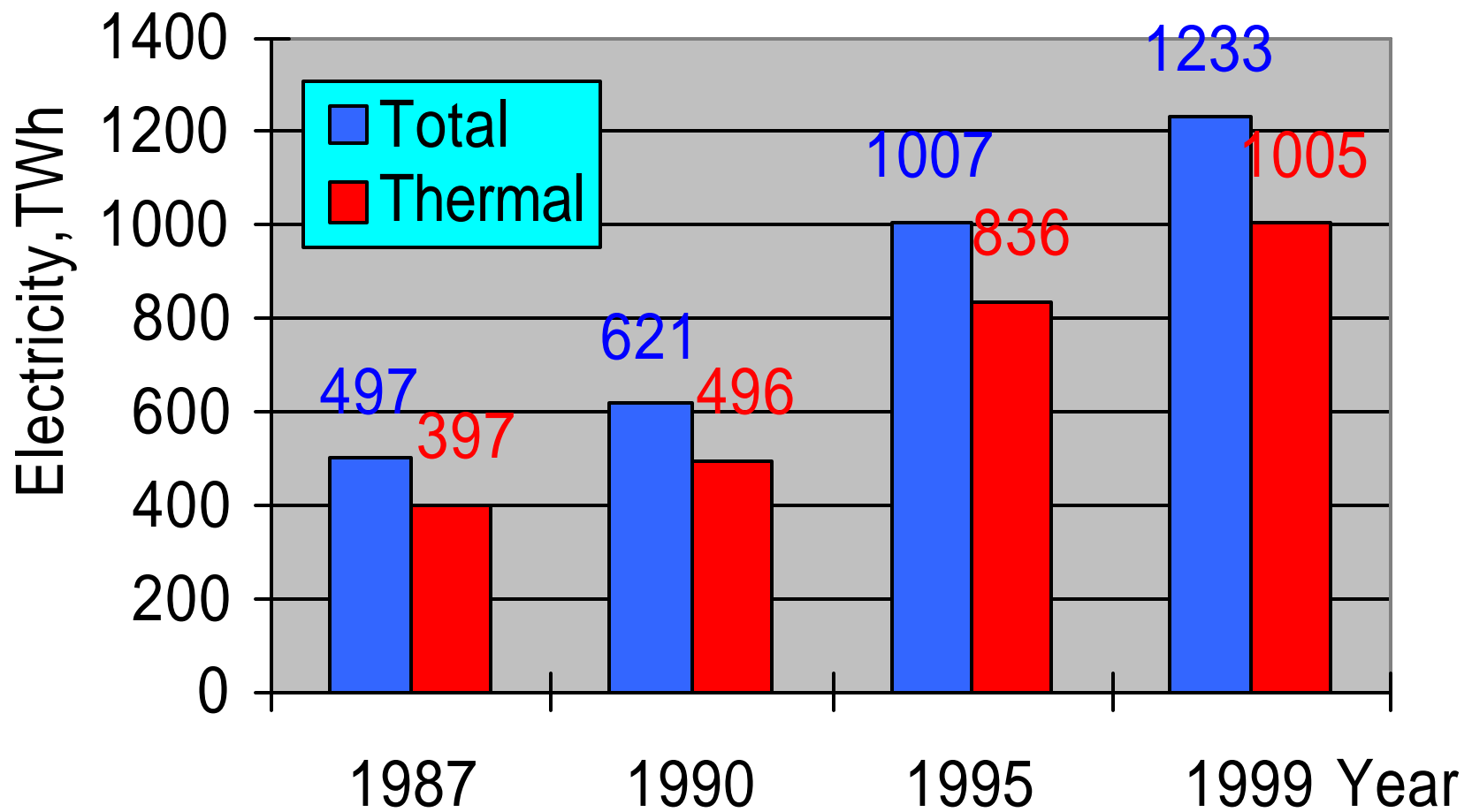
# Development Status of Electric Power Industry in China

- Since 1980s, China's electric power industry has achieved rapid development.
- Newly installed generating capacity had been reached over 15GW annually from 1991 to 1999.
- The total installed generating capacity reached 100GW in 1987 and exceeded 200GW in 1995.
- By the end of 1999, the national total generating capacity had been amounted to 298.8 GW with a total electric power production of 1233TWh.
- As of the end of April in 2001, China's total installed generating capacity has surpassed 300GW.

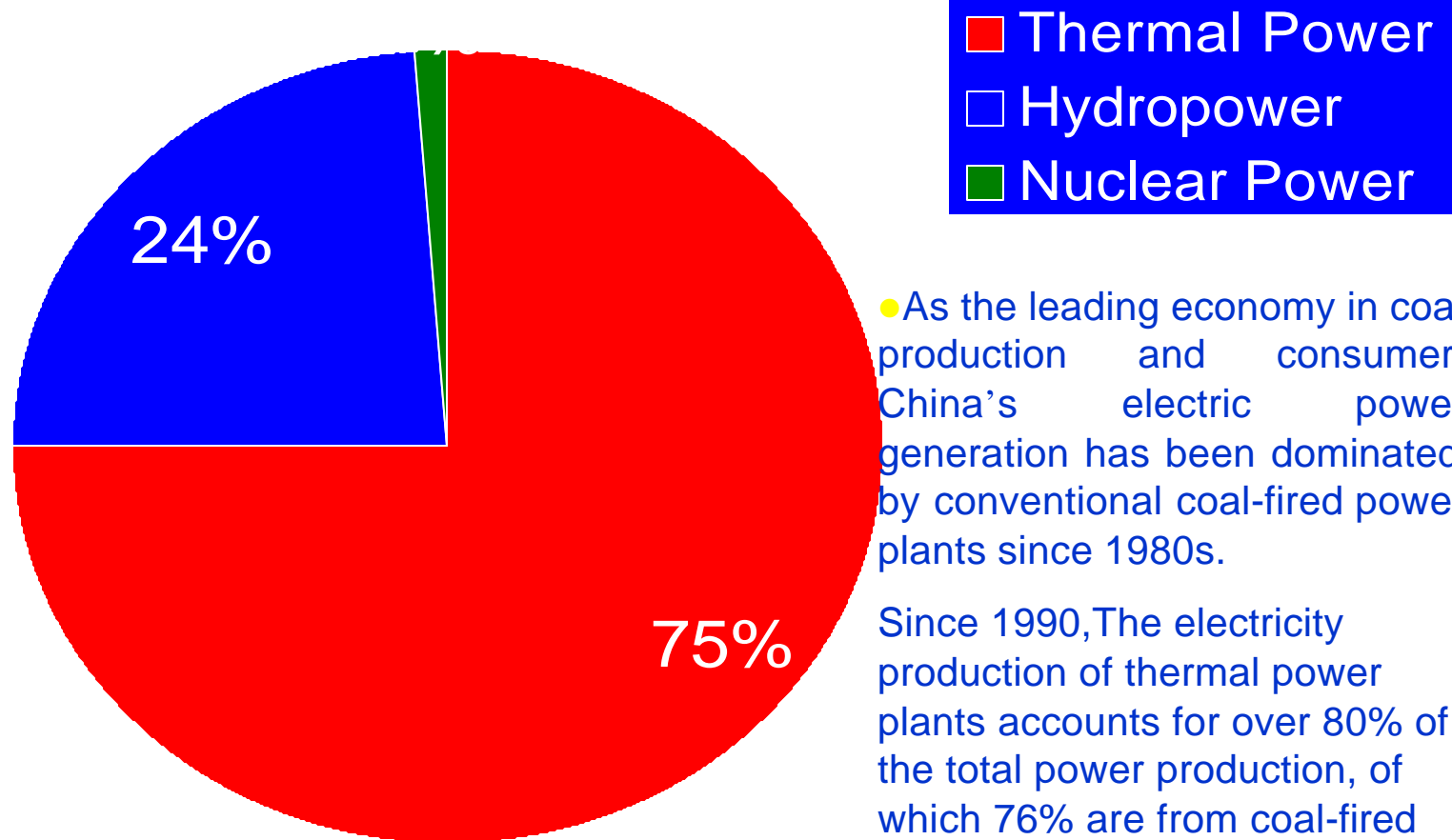
# Total Installed Generating Capacity from 1987 to 1999 in China



# Annual Electricity Generation from 1987 to 1999 in China



## Composition of Installed Generating Capacity in China's Electric Power Industry



● As the leading economy in coal production and consumer, China's electric power generation has been dominated by conventional coal-fired power plants since 1980s.

Since 1990, The electricity production of thermal power plants accounts for over 80% of the total power production, of which 76% are from coal-fired power plants

# Development Status of China's Electric Power Industry

- As the leading economy in coal production and consumer, China's electric power generation has been dominated by conventional coal-fired power plants since 1980s.
- By the end of 1999, there were total 81 power plants each with installed capacity of 1000MW and above, of which,
  - 14 hydropower plants,
  - 66 thermal power plants
  - 1 nuclear power plants
- Another 23 such power plants are under construction.

# Composition Structure of Thermal Power Plants in China in 1999

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Less than 100	About 2800	About 70000	About 31	

# Development Status of China's Electric Power Industry

- China's electric power generation is dominated by thermal power plants with relative low share of large size units.
- Combined capacity with units each rated at 500MW and above only accounts for less than 6% of the total thermal capacity.
- The combined capacity of the units each rated at 300MW and above accounts for 36%, units each rated at 100-220MW being 33%, and the rest units each rated below 100MW being 31%.
- There are still more than 40000MW of small units each rated at 50MW and below accounting for about 18% of the total thermal capacity.

## Develop Supercritical Units to Optimize China's Thermal Power Structure

- The State Power Corporation of China has implemented a plan to shutdown and close certain capacity of small coal-fired units step by step.
- Phase I: A total 7740MW capacity of small units will be shutdown and closed from 1998 to 2001.
- Phase II: Another total 6250MW capacity of small units will be shutdown and closed from 2001 to 2004.
- A total capacity of 14000MW small coal-fired units will be shutdown by the end of 2004.
- A large capacity space for the development of the advanced large size thermal units.

## Develop Supercritical Units to Optimize China's Thermal Power Structure

- supercritical units have higher plant efficiency because of the higher steam parameters
- The net plant efficiency of the supercritical units employed the steam parameters of 24.1MPa/538/538 is about 2.25% higher than that of the sub-critical units with the steam parameters of 17.1MPa/538/538
- The net plant efficiency of the ultra-supercritical units with the steam parameters of 31MPa/566/566 is about 4.6% higher than that of the above sub-critical units

## Development Trends of Supercritical Units in Industrial Economies

- Supercritical and ultra-supercritical units have been developed into proven and mature technologies worldwide.
- Over hundreds coal-fired supercritical units have been successfully into operation for many years worldwide.
- Several large size supercritical units employed the steam parameters of 28.0-30.0MPa/580 /600 have been into commercial operation with net plant efficiency over 45%
- The largest supercritical unit has reached 1300MW
- The 1000MW class supercritical units with the steam parameters of 31MPa/600 /600 to be developed in industrial economies.

## Develop Supercritical Units to Optimize China's Thermal Power Structure

- Current level of net coal consumption rate  
Supercritical units: 310g/kWh  
Ultra-supercritical units: 290 g/kWh
- Current level of coal consumption rate in China  
Average : 390g/kWh, small thermal units: 550g/kWh  
80g/kWh higher than supercritical unit  
100g/kWh higher than ultra-supercritical units.
- To develop large size coal-fired supercritical units with high steam parameters will be the most effective technical solutions for China to optimize its electric power structure. This will greatly improve coal utilization efficiency and reduce pollutant emissions in the near future

# Current Application of Supercritical Coal-fired Units in China

- To date, there are over 10 supercritical units have been into operation and more than 10 supercritical units have been approved or planned to be constructed.
- The first 600MW supercritical pressure units were put into operation in succession in 1990s .
- Two 600MW units supplied by ABB were commissioned at Shanghai Shidongkou No.2 Power Plant in 1992.
- Supercritical units imported from Russia have a total capacity of 4800MW.
- All supercritical units currently under operation or construction in China are imported ones.
- These units are in stable operation after testing and adjustment. The Chinese technical personnel and operators have got a better understanding to the operation technology for these supercritical units.

# Technical Routines for China to Develop Supercritical Coal-fired Units

- Chinese government has listed the development of the supercritical units as one of the key project on the research & development of equipment and domestic manufacture during the 10th five-year plan.
- The State Planning and Development Commission has approved to build two 600MW supercritical units as the demonstration project for domestic development of supercritical units at the Qinbei Power Plant in Henan Province.
- The State Economic and Trade Commission has provided special sponsorship for the domestic development of supercritical units.

## Technical Routines for China to Develop Supercritical Coal-fired Units

- For demonstration project to built two 600MW supercritical units at Qinbei Plant, China will take the policy to import equipment as well as the design and manufacture technology, meanwhile to increase the proportion of sub-contracted key equipment manufacture domestically.
- It is aimed that 70% of the equipment for the first two supercritical units to be manufactured domestically.
- The unstable operation period for the first domestic supercritical unit should be within one year and its availability should be not less than 85%.

# Technical Routines for China to Develop Supercritical Coal-fired Units

## Some Considerations on Selection of Steam Parameters

- Since 1990s worldwide, the advanced supercritical units each rated at 600MW have employed increasing steam parameters from 24.2MPa/538/566 to 24.2MPa/566-580/566-580 and is currently approaching to 24.2MPa/600/660 .
- The supercritical units currently under operation in China employ the steam parameters of 24.2MPa,538/566 .
- It is suggested that the supercritical units to be developed in China be based on 600MW unit and employ steam parameters of 24.2MPa,566/566 .

## Concluding Remarks

In order to meet the increasing demand for China's electric power development as well as to improve coal utilization efficiency and reduce pollutant emissions from coal fired power plants, China will take effective measures to optimize the thermal power structure through combination of technology and equipment import to greatly develop domestic supercritical units.